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# AN APPROACH FOR IRRIGATION NETWORK REHABILITATION PRIORITY BASED ON HYBRID AHP-TOPSIS, WASPAS, MOORA

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**ABSTRACT:** Floods that frequently hit the Jompo Watershed (DAS) area cause damage to irrigation networks. The magnitude of the damage certainly requires much money, while the maintenance funds are minimal and not comparable to the area of the irrigation network. This research aims to select the most appropriate priority for network rehabilitation to produce the maximum benefits. Compiling priorities uses the Analytic Hierarchy Process (AHP) method, but it contains subjectivity in the preparation of AHP. Therefore, to reduce its subjectivity, this study integrates AHP with the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) method, Weight Aggregated Sum Product Assessment (WASPAS), and Multi-Objective Optimization by Ratio Analysis (MOORA). Rehabilitation criteria assess the performance of irrigation networks by using the condition of damage to buildings (A1), availability of water (A2), area of irrigation (A3), and crop productivity (A4). The results of AHP-TOPSIS [0.1], AHP-WASPAS [0.0.8], and AHP-MOORA are effectively used in decision-making in rehabilitating irrigation networks. In addition, the results can represent the performance of irrigation networks. The priority to be rehabilitated is the Pangarengan (B3) irrigation network, with preference values of 0.72, 0.81, and 0.33.

*Keywords: Priority rehabilitation irrigation network, AHP, TOPSIS, WASPAS, MOORA*

## 1. INTRODUCTION

Flash floods with high peak discharges and sudden arrivals cause damage to irrigation canal structures, and weir breaks [1]. The impact of this damage is decreasing in the function of the irrigation network system. This flash flood incident also occurred in the Jompo River Basin, which damaged nine dams and inundated 362 hectares of rice fields spread over eight villages in 2 sub-districts [2]. The 2021 budget deficit for the Jember district government of IDR 800 billion is an obstacle to this construction improvement as a whole [2]. In limited budget conditions, implementing construction development becomes a challenge in determining the priority scale.

For the sustainability of construction management, the determination of handling priorities must refer to the performance assessment of irrigation networks [3,4]. In Indonesia, irrigation network performance assessment refers to the regulation Minister of Public Works of the Republic of Indonesia number 32/PRT/M/2007. Several studies have referred to the rule by considering other criteria. The addition of a plan assessment on the application of water distribution for crop productivity as a sub-criteria shows an increase in every aspect of the performance component of the irrigation network system [5]. Another factor affecting irrigation performance is the physical aspect, such as the existence of infrastructure [6]. Used irrigation network maintenance criteria such as area, irrigation status, and intake distance from the office warehouse using the Simple Additive Weighting (SAW) method to determine the weighting [7].

Furthermore, selecting irrigation maintenance priority uses criteria of irrigation performance levels, irrigation status, estimated cost, area, and distance intake from the office warehouse using the Analytic Network Process (ANP) to weighting [3]. The disadvantage of this criterion is that not all respondents consider the research necessary to use alternatives. However, the criteria in several previous studies used the system performance index from the Regulation Minister of Public Works of the Republic of Indonesia Number 32/PRT/M/2007, which gave a score sequentially from the lowest.

Multiple-Criteria Decision Making (MCDM) is one of the fastest-growing fields. The MCDM approach has solved various problems with solving multiple complex decision-making problems. One of them is the selection of priorities in rehabilitating irrigation networks. The AHP has been applied to overcome the complex issues in determining the relative weight essential criteria related to the repair and rehabilitation of irrigation networks. However, the main disadvantage of MCDM methods, such as the AHP approach, is the uncertainty transformed from the pairwise comparison matrix, which is usually characterized by the non-reciprocal property [8]. Besides the AHP method, several

MCDM methods have been used to select rehabilitation priorities, including AHP, ANP, SAW, Elimination Et Choix Ia Reality (ELECTRE), Weighted Product (WP), and TOPSIS [9,10]. The combination of MCDM is usually used to determine the uncertainty potential for alternative weights that can be applied to find optimal water resource management solutions [11]. For example, the application of the integration of the AHP-TOPSIS method has an essential role in accelerating the priority determinations for rehabilitating and maintaining optimal irrigation networks [9]. In addition, several MCDM methods have been successfully applied to other problems. The WASPAS method has been used to analyze the efficiency of agricultural enterprises in Serbia, whose results can be positively influenced by many macro and micro factors [11]. This method could reduce errors or optimize weight to select the highest and lowest scores [13]. Besides that, the MOORA method has an excellent selective level in determining an alternative [14,15]. All attributes and their relative importance are considered together in MOORA, which provides the most stable and accurate evaluation [13].

A combination method can provide more useful, broader, and profound problem information. It can also reduce uncertainty by providing additional information and decision-makers to make the results reliable. Based on previous research, the classification of criteria in the Regulation Minister of Public Works of the Republic of Indonesia number 32/PRT/M/2007 is appropriate in determining the performance of irrigation networks. In this case, a hybrid of the AHP model with WASPAS and MOORA priority can determine irrigation structures rehabilitation, which has never been applied to the rehabilitation of irrigation networks to demonstrate the effectiveness of the AHP method. Referring to the success of the TOPSIS method in solving similar problems, this method also applies as a comparison between the two processes. In testing the model stability, use validation and exploration of each technique. This research was conducted in the Jompo Watershed Irrigation Area due to the damage in each irrigation area affecting the performance of the irrigation network, so rehabilitation needs to prioritize producing optimal irrigation structures.

## 2. RESEARCH SIGNIFICANCE

The rehabilitation priority of irrigation networks due to flood and other damage is needed to maximize benefit. Various MCDMs have been developed to determine priority, including the AHP. Still, the disadvantage of the AHP method is that decision-making is strongly influenced by personal opinion, thus allowing bias [11,16]. Therefore, the hybrid AHP is an approach that can explore more in-depth, comprehensive, and valuable knowledge and information. It can also reduce bias and provide complementary information to increase credibility and trustworthiness. This research has produced an appropriate and proper prioritization for maintaining irrigation networks to maximize benefits with a limited maintenance budget based on the irrigation areas in the region.

## 3. METHOD

### 3.1 Study Area

This research location is the irrigation area of the Jompo Watershed Irrigation Network, Patrang District, Jember Regency, East Java Province. The flow of the Jompo River was used for nine Irrigation Areas (IA) in Fig. 1 on the Jompo watershed. They are listed in Table 4. The total area is about 1,088 ha. In some of the Irrigation, The Jompo River has a length of 28.30 km and an average width of 30 m. The basis for choosing the location of the Jompo watershed is the loss of the physical condition and function of irrigation structures due to flooding.

### 3.2 Research Procedure

This research consists of three stages to determine the irrigation network rehabilitation priorities. The first stage is classifying irrigation network performance and choosing the criteria weight for each parameter with the AHP method approach. The next stage is determining priority by ranking each preference with the help of TOPSIS, WASPAS, and MOORA. The following outlines the steps in the research framework, as seen in Fig. 2.

*2.2.1 Classification of irrigation network performance criteria*

The category for the structure's condition is assessed based on the measurement of the level of damage and the function of irrigation structure damage, which is shown in Table 1 and Table 2 [9,17]. The process of interpretation and assessment of the condition of irrigation structures was carried out with the Coordinator of UPT Water Resources Sub-watershed Jompo.

The irrigation structure's performance was measured to determine whether its function was still running according to its role. The functioning of the irrigation network structures is classified according to Table 2.

The criteria for water availability are measured by evaluating the fulfillment of water needs in a paddy field. Water availability is measured by how many times it is given in one year, shown in Table 3.

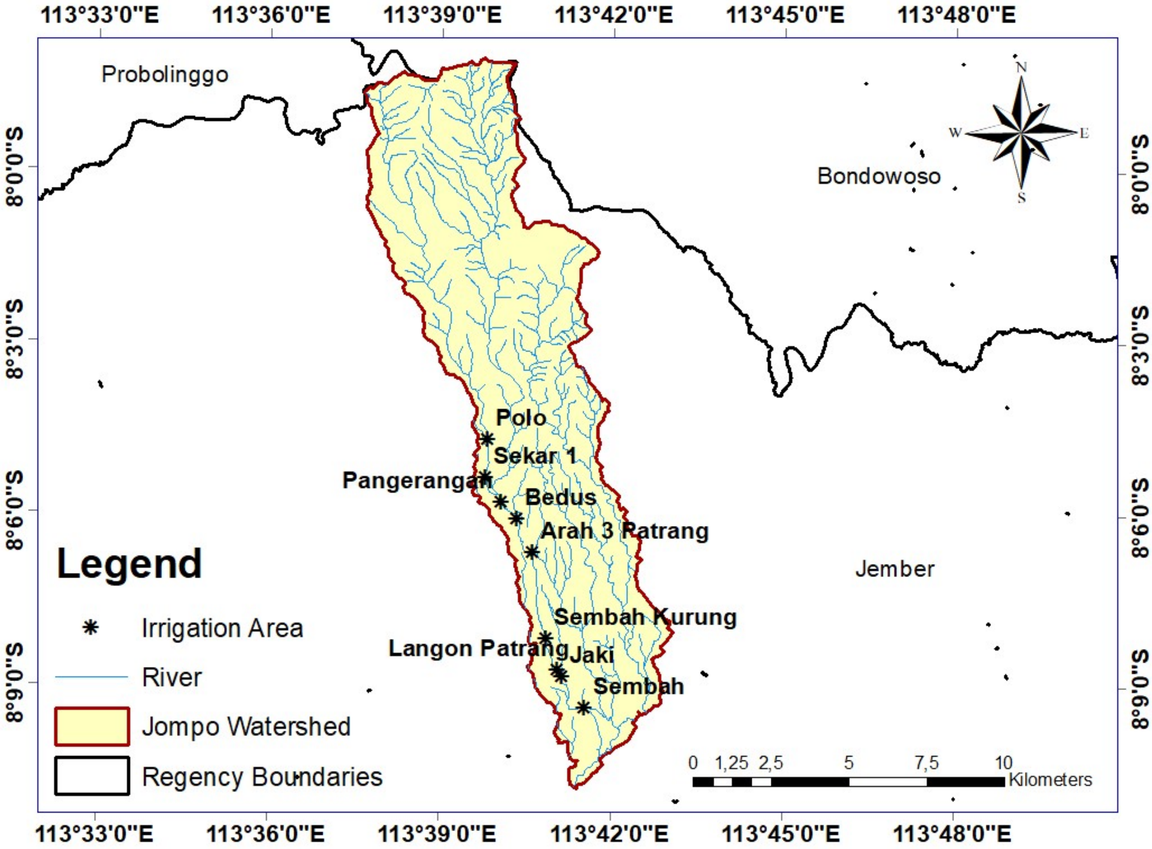


Fig. 1 Jompo Watershed Irrigation System

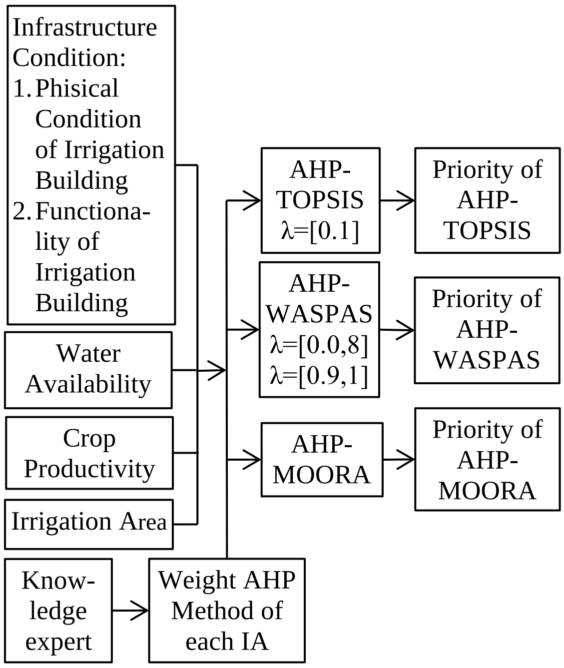


Fig. 2 The research framework [10,12,13]

*2.2.2 Determination of Criteria Weight Using AHP*

The AHP technique was introduced by Saaty, which was intended to determine the priority of several alternatives and their relative importance based on the attributes in the decision-making problem of several criteria [19]. The steps for determining the weight of each criterion for the AHP method were as follows.

1. Create a hierarchy by defining goals, criteria, and indexes.
   A complex problem-solving system was easy to understand with more minor elements. Problem-solving is done by determining the goals resulting from comparing each criterion, which is a factor in the influence of the goals or indicators to be achieved. After identifying the problems and their relationship, a hierarchical structure model consisting of goals, criteria, and indexes can be shown in Table 4. Each index in the table follows the principles of overall integrity and relative independence.
   This research aims to prioritize irrigation network rehabilitation in the Jompo sub-watershed. The criteria selected from the Regulation Minister of Public Works of the Republic of Indonesia number 32/PRT/M/2007.
2. Construct and perform judgment.
   The determination of respondents was done by referring to previous research. In this research, 15 respondents were selected to be imported by the AHP method into weighting criteria as an alternative. They were assigned the value of each relative importance for two elements at a

specific index related to the index above it to give a priority order. The assessment results are presented in a pairwise comparison matrix form. The quantitative evaluation scale from 1 to 9 can be seen in Fig. 3.

3. Select the priority value of the criteria by adding up the resulting row matrix and dividing by the number of criteria. This step is the column normalization process.
4. Testing the consistency of each paired matrix is an essential principle in the AHP method. Determination has two purposes. Firstly, similar objects can be classified according to similarity and conformity. The second is the relationship level between objects based on specific criteria.

Calculating the consistency index (CI) using Eq. (1)

$$\boldsymbol{CI} = \frac{\boldsymbol{\lambda}\ \mathbf{maks} - \mathbf{n}}{\mathbf{n}-\mathbf{1}} \quad (1)$$

Consistency Ratio (CR) was calculated with Eq. (2). With CI being the consistency index, λ max was the largest eigen value of a matrix of order n, and n was the criteria number. The largest eigen value was obtained by adding up the multiplication result of the column with the priority vector.

$$\mathbf{CR} = \frac{\mathbf{CI}}{\mathbf{RI}} \quad (2)$$

The Random Index (RI) value is based on Saaty's calculation in Table 5.

Table 1 Classification of irrigation network conditions

| Classification | Score | Damage Percent | Description: Code: 32/PRT/M/2007 | Description: Pradipta *et al.*, 2020 |
|---|---|---|---|---|
| Good | 4 | <10% | Minor damage, no extensive repair needed | Both functionally and physically |
| Slightly damaged | 3 | 10%-20% | The average condition was severe and required considerable maintenance | The plaster was peeling off, or there was light vegetation |
| Medium broken | 2 | 21%-40% | Para condition, service can be carried out, but requires considerable maintenance work. | Experiencing cracks and displacement of all or part of the building |
| Heavily damaged | 1 | >40% | The damage was severe, and the service could not be entirely carried out, requiring significant repairs | the collapse of irrigation structures |

*Note: Source [18]*

Table 2 Classification of irrigation structures function

| Classification | Description |
|---|---|
| Good | The sluice gate structures can be operated, flow the design discharge, and the measuring building can function and measure correctly. |
| Deficient | The sluice gate structures were operable, drains the design flow, and the gauge building may not measure correctly, but it works. |
| Poor | The floodgate structures cannot be operated or flow the designed water flow, and the measuring building cannot measure or function properly. |
| Not Working | The door cannot operate, the water discharge cannot drain canal structures, the measuring construction cannot measure, and the constructions do not function properly. |

*Note: Source: [7]*

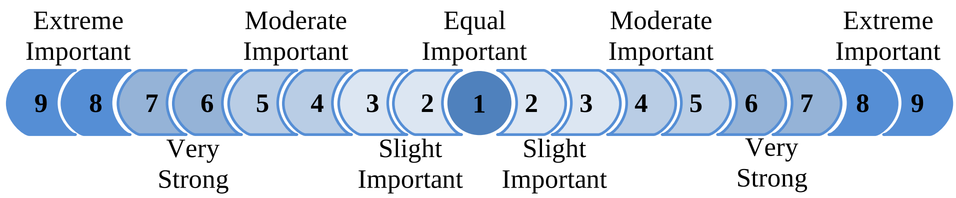


Fig 3 Analytic Hierarchy Process Scale [19]

Table 3 - Water availability criteria

| Criteria | Classification |
|---|---|
| Good | There is water all year round |
| Deficient | No running water for less than 3 months |
| Poor | No running water for 3-6 months |
| Not eligible | No running water for more than 6 months |

*Note: Source: [18]*

Table 4 Hierarchical Structure Model

| Goal | Criterion | Index |
| --- | --- | --- |
| Selection of rehabilitation in irrigation networks | The condition of irrigation structures damage (A1) | IA Polo (B1) |
| | Water availability (A2) | IA Sekar (B2) |
| | Irrigation area (A3) | IA Bedus (B3) |
| | Crop productivity (A4) | IA Pengarengan (B4) |
| | | IA Langon Patrang (B5) |
| | | IA Arah 3 Patrang (B6) |
| | | IA Sembah (B7) |
| | | IA Jaki (B8) |
| | | IA Sembah Kurung (B9) |

*Note: Source: [7]*

Table 5 - Random generator values

| N | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| RI | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 | 1.51 | 1.58 |

*Note : Source: [19]*

*2.2.3 Priority Determination Using TOPSIS*

The preferences in the TOPSIS are calculated by ranking alternatives based on the weight of the criteria generated from the previous points. The advantage of using this method is that it is straightforward, and the concept is rational. It is easy to understand and can be assessed relative performance in forming simple mathematical forms. According to [20], the steps in the TOPSIS method are:

1. Calculate the performance branch by determining the normalized matrix ($r_{ij}$) with the following Eq. (3)
   $$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x^2}} \quad (3)$$
2. Calculate twig weights by determining the normalized matrix ($y_{ij}$) with the following Eq. (4)
   $$y_{ij} = w_j \cdot r_{ij} \quad (4)$$
   With $\sum_{j=1}^{n} w_j = 1$
   $w_j$ is the weight of several criteria with a total value of 1.
3. Determine the solution matrix in positive and negative ideals with the following Eq. (5)-(8)
   $$A+ = (y_1^+, y_2^+, \ldots, y_n^+) \quad (5)$$
   $$A- = (y_1^-, y_2^-, \ldots, y_n^-) \quad (6)$$
   Where,
   $$y_j^+ = \begin{cases} \max y_{ij} \text{ ; if j is the benefit} \\ \max y_{ij} \text{ ; if j is cost} \end{cases} \quad (7)$$
   $$y_j^- = \begin{cases} \max y_{ij} \text{ ; if j is cost} \\ \max y_{ij} \text{ ; if j is the benefit} \end{cases} \quad (8)$$
4. Calculate the distance between each alternative value with a positive ($D_i^+$) and a ($D_i^-$) negative ideal solution matrix using Eq. (9) and (10)
   $$D_i^+ = \sqrt{\sum_{j=1}^{n} (y_{ij} - y_j^+)^2} \text{ ; i= 1, 2, ..., m} \quad (9)$$
   $$D_i^- = \sqrt{\sum_{j=1}^{n} (y_{ij} - y_j^-)^2} \text{ ; i= 1, 2, ..., m} \quad (10)$$
5. Determine the value of preference or each alternative (Vi) by Eq. (11).
   $$V_i = \frac{D_i^-}{D_i^- + D_i^+} \text{ ; } i = 1, 2, \ldots, m \quad (11)$$

The largest $V_i$ value indicates that the alternative can be chosen.

*2.2.4 Priority Determination Using WASPAS*

WASPAS was proposed by [21]. It integrated two approaches to MCDM: the Weight Product (WP) and the SAW method. WP and SAW methods require matrix elements and linear normalization. The WASPAS method solves various complex problems and provides better results according to the decision support system [12]. The step of applying the WASPAS method was written below [22].

1. Prepare a Matrix of data $x_{ij}$ , with i and j denoting the number of alternatives and criteria.
2. Normalize $x_{ij}$ to be normalized performance rating ( $r_{ij}$ ) is calculated as Eq. (12)-(13):
   $$r_{ijmax} = \frac{x_{ij}}{max_i(x_{ij})} \text{ denotes the benefit criteria} \quad (12)$$
   $$r_{ijmin} = \frac{min_i(x_{ij})}{x_{ij}} \text{ denotes the cost criteria} \quad (13)$$
3. Calculate the relative preference based on the SAW method ( $Q_i^{(1)}$ ) and the relative importance of the WP method ( $Q_i^{(2)}$ ), is calculated as Eq. (14)-(15):
   $$Q_i^{(1)} = \sum_{j=1}^{n} w_j r_{ij} \,. \quad (14)$$
   $$Q_i^{(2)} = \prod_{j=1}^{n} r_{ij}^{w_j} \quad (15)$$
4. Calculate the preference value as Eq. (16).
   $$Q_i = \lambda Q_i^{(1)} + (1 - \lambda) Q_i^{(2)} = \lambda \sum_{j=1}^{n} w_j r_{ij} + (1 - \lambda) \prod_{j=1}^{n} r_{ij}^{w_j} \text{ , where } \lambda \in [0, 1] \quad (16)$$

When decision-makers do not have preferences over the coefficient, the value is 0.5, and Eq. (5) is expressed as Eq. (17).

$$Q_i = 0.5 Q_i^{(1)} + 0.5 Q_i^{(2)} = 0.5 \sum_{j=1}^{n} w_j r_{ij} + 0.5 \prod_{j=1}^{n} r_{ij}^{w_j} \quad (17)$$

*2.2.5 Priority Determination Using MOORA*

MOORA was introduced by Brauers, who successfully implemented it in various complex manufacturing problems [13]. MOORA was implemented to find the efficiency of optimizing some performance characteristics for decision-making.

Steps in the application of MOORA, namely:

1. Design a decision matrix with different performance alternatives with various criteria [23]
2. Combinate the AHP and MOORA methods that use the Geometric Mean to calculate group decisions.
3. Input the AHP criteria weight into the MOORA method.
4. Normalize the decision matrix [24]

Furthermore, the MOORA method was used to normalize alternative data. Normalization using MOORA is calculated in Eq. (18)-(19).

$$\mathbf{X}_{ij}^{*} = \frac{x_{ij}}{\sqrt{[\sum_{j=1}^{m}(x_{ij})^2]}} \quad (18)$$

$$\mathbf{y}_{j}^{*} = \sum_{j=1}^{n} \mathbf{w}_{j}\mathbf{X}_{ij}^{*} \quad (19)$$

## 4. RESULTS AND DISCUSSION

### 4.1 Assessment of Irrigation Network Performance Criteria

The performance of irrigation network assessment results based on the irrigation structures' condition and water availability criteria are assessed according to the classification in Tables 1, 2, and 3. In addition, the criteria of an irrigation and crop productivity area are calculated based on the proportion of paddy field area and yields.

The condition of irrigation structures assessment results in the Jompo watershed found four different levels of damage in nine irrigation areas, as seen in Table 6. The level of damage in the hefty damage is obtained in four B, namely B1 (49.36%), B3 (51.23%), B4 (89.36%), and B9 (64.77%). The damage level is medium on B5 (30.84%) and B7 (21.55%). The level of light damage is on B8 (20.00%) and B6 (16.96%), while for light conditions, only on B2 (2.86%).

The value of water loss and water coverage in irrigation areas measures the irrigation structure's performance. The value of water loss on the Jompo watershed in 2021 in nine irrigation structures shows that only four decreased irrigation structures. Sequentially the highest water losses are B5 (8.55 $m^3/s$), B2 (4.03 $m^3/s$), B6 (2.93 $m^3/s$), and B3 (2.71 $m^3/sec$).

The value of water coverage in the irrigation area is the difference between the number of needs and the availability of the 10-day average discharge data. Fig. 4 shows an overview of water coverage in four B, namely B3 (-4.20 $m^3/s$), B6 (-4.09 $m^3/s$), B2(-3.99 $m^3/s$), and B5 (-2.99 $m^3/s$). The minus value on water availability indicates that the irrigation area in the Jompo watershed has not been fulfilled optimally. The percentage of the average value of water loss and the value of water availability can be seen in Fig. 4.

The relationship between the irrigated area and the value of crop productivity. The value of the area of irrigation influences the rehabilitation of irrigation networks. Crop productivity is one of the criteria determining an irrigation network's priority rehabilitation. Crop productivity is assessed based on the paddy field area drained by the irrigation network. The most significant productivity value in five weirs (B) is B6, B9, B8, B5, and B7, with a 6.2 ton/ha for more details, as shown in Table 7.

Table 6 Value of physical condition of irrigation buildings

| Weir name | Total Damage (%) | Dam Condition | Description |
|---|---|---|---|
| B1 | 49.36 | Heavy Damage | - Need improvement on the left wing |
| | | | - Need improvement on drain intake |
| | | | - Needs handling on the weir lighthouse |
| B2 | 2.86 | Good | - Under repair |
| B3 | 51.23 | Heavy Damage | - Need improvement on the left wing |
| | | | - Need a repair on intake |
| | | | - Needs handling on the weir lighthouse |
| B4 | 89.36 | Heavy Damage | - Requires handling on all dam buildings |
| B5 | 30.84 | Medium Damage | - Need improvement on the left wing |
| | | | - Need a repair on intake |
| B6 | 16.96 | Light Damage | - Needs improvement on the right wing of the weir |
| B7 | 21.55 | Medium Damage | - The condition of the building is still good |
| B8 | 20.00 | Light Damage | - Needs handling on the weir lighthouse |
| B9 | 64.77 | Heavy Damage | - Needs repair on the weir wing |
| | | | - Need improvement on the lighthouse |
| | | | - Needs repair on the door |

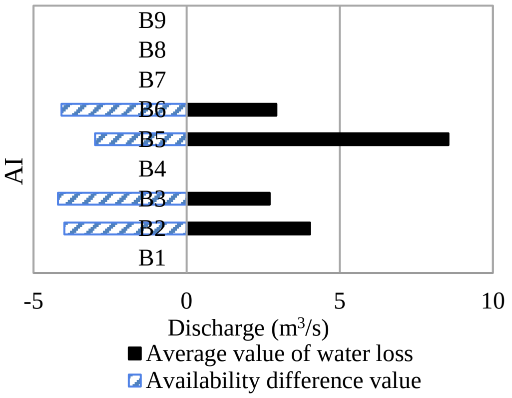


Fig. 4 Average value of water loss and water availability value

Table 7 Irrigation area and crop productivity

| No | IA | A2 ($m^3/s$) | A3 (ha) | A4 (ton/ha) |
|---|---|---|---|---|
| 1 | B1 | 0.00 | 100 | 5.60 |
| 2 | B2 | -3.99 | 251 | 5.60 |
| 3 | B3 | -4.20 | 267 | 6.18 |
| 4 | B4 | -4.09 | 10 | 5.60 |
| 5 | B5 | 0.00 | 97 | 6.20 |
| 6 | B6 | -2.99 | 233 | 6.20 |
| 7 | B7 | 0.00 | 42 | 6.20 |
| 8 | B8 | 0.00 | 63 | 6.20 |
| 9 | B9 | 0.00 | 25 | 6.20 |

### 4.2 Estimation of Weighted Using AHP

Normalization on the AHP method is done by dividing the element values with the column values. The eigenvector value is generated based on the criteria number for each row. After obtaining the eigenvector for each criterion, we get the CI value is 0.2986 and CR 0.0747. Because CR is less than 0.1, the weight of each criterion be consistent, so the calculation for the next step can be continued. The calculation can be used as a criterion weight. The weighted criteria results are shown in Fig. 5. In general, based on weight estimation using AHP, sequentially from the most significant weight is irrigation structures condition, water availability, irrigation area, and crop productivity.

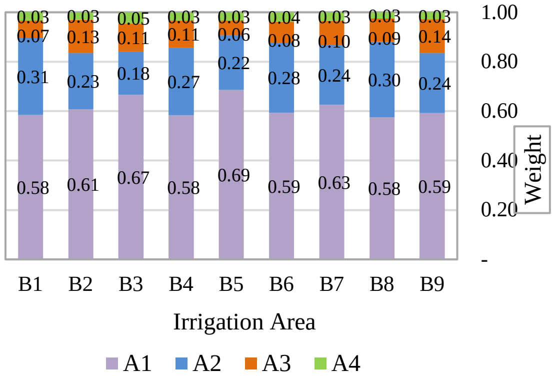


Fig. 5 Weighted criteria using AHP

### 4.3 The Hybrid AHP-TOPSIS Method for Rehabilitation of Irrigation Network Application

Based on the weight of the criteria from the AHP result, the normalization of each criterion is carried out using the TOPSIS method. The normalization results are multiplied by the criteria weight from the AHP method to get a priority scale in the next step. From these results, the maximum and minimum values for each irrigation area are calculated, and the criteria for making the values of the Positive Ideal Solution ($D_i^+$) and the Negative Ideal Solution ($D_i^-$). After obtaining the $D_i^+$ and $D_i^-$ values, the preference values for the primary rehabilitation of irrigation networks are determined, as shown in Fig.6.

The effect of weight on AHP-TOPSIS is still the same as the weight of AHP itself. This means that the influence of AHP is still strong compared to the TOPSIS method.

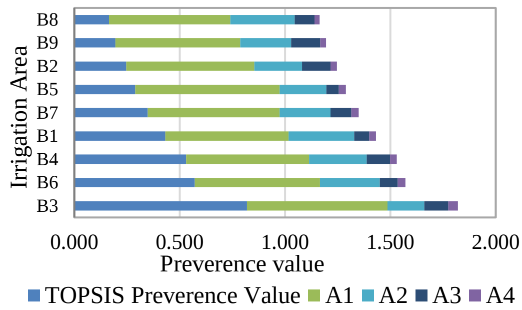


Fig. 6 Preference value of irrigation network rehabilitation using AHP-TOPSIS method

### 4.4 The AHP-WASPAS Method for Rehabilitation of Irrigation Network Application

The water coverage for the element of the irrigation network has minus and positive values. The minus value on water availability indicates that the irrigation area that flows in the Jompo watershed has not been fulfilled optimally. But, in the WASPAS method, the minus value will cause inconsistent relative importance. Therefore, a score of less than 5 indicates that water availability in the irrigation area that flows in the Jompo watershed has not been optimally fulfilled. Modifying the data without changing the meaning and arrangement of the original values is required. In this case, the smallest minus value is -4.20 $m^3/s$, all values on the water availability criteria are added by 5, so the minimum score is 0.8 $m^3/s$. After getting alternative values that have already been processed, continue using the WASPAS method to calculate the preference value to determine the priority for rehabilitation of irrigation network performance. Starting from the alternative normalization calculation as Eq. (10) - (11). The following alternative can be calculated using the same formula to generate the priority and rating values shown in Fig.7.

In contrast to the AHP-TOPSIS approach, the AHP-WASPAS approach is not affected by the consistent strength of the AHP weights. Based on Fig. 10, the AHP-WASPAS method has a preference value that depends on the variance value of each criterion. The smaller the value of the variance of each criterion, the stronger the effect on the preference value.

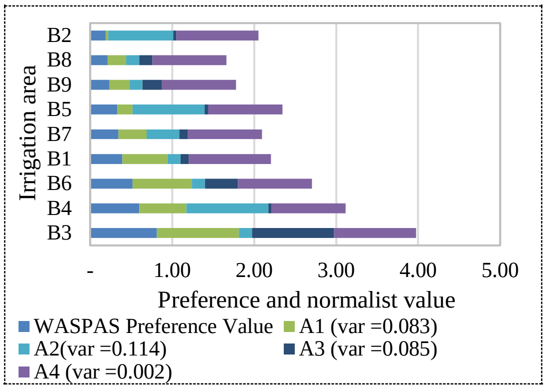


Fig. 7 Alternative normalization using the WASPAS

### 4.5 The Hybrid AHP-MOORA Method for Rehabilitation of Irrigation Network Application

The priority calculation in the AHP-MOORA method begins with a decision matrix as an alternative value for the irrigation area criteria. Based on predetermined alternative data, calculate the AHP-MOORA method's normalization value with the Eq. (16) and the results shown in Fig. 8. The criteria that strongly influence the magnitude of the preference value are A1, A2, and A4.

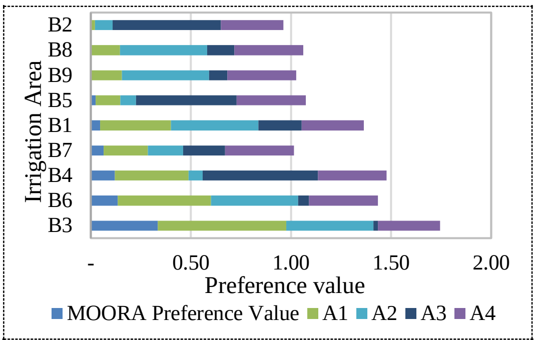


Fig.8 Alternative Normalization using MOORA

After obtaining the alternative normalization value, the calculation of the preference value in AHP-MOORA continues with the preference value estimate. The ranking of preference is not influenced by the amount of the normalized value of each alternative but is influenced by the ratio of each criterion value. The AHP weight does not strongly affect the value of the MOORA preference.

### 4.6 Ranking of Rehabilitation of Irrigation Network

The consistency of the AHP-TOPSIS and AHP-WASPAS methods is tested by treating various values of Lambda [0,1] in Table 8. In AHP-TOPSIS, all lamda values produce a consistent sort order. While the AHP-WASPAS method, the results produce two groups of priority order, namely Lamda [0,0.8] in order of B3>B4>B6>B1>B7>B5> B9>B8>B2 and Lambda sequence [0.9,1] with order B3>B4>B6>B1>B7>B5>B9>B2>B8. Details can be seen in Table 8. These results can be concluded that AHP-TOPSIS is more consistent than AHP-WASPAS.

Table 8 Comparison MDMC Priority based on Lamda Validation

| Method | Lamda | Priority Alternative |
|---|---|---|
| AHP-TOPSIS | All value [0,1] | B3>B6>B4>B1>B7>B5> B2> B9>B8 |
| AHP-WASPAS | All value [0,0.8] | B3>B4>B6>B1>B7>B5> B9> B8>B2 |
| | [0.9,1] | B3>B4>B6>B1>B7>B5> B9> B2>B8 |
| AHP-MOORA | | B3>B6>B4>B7>B1>B5> B9> B8>B2 |

Four irrigation network performance criteria in B show as an alternative to the rehabilitation of relatively stable irrigation networks. The preference values in the calculation of AHP-TOPSIS, AHP-WASPAS, and AHP-MOORA are sorted from the most prioritized in the rehabilitation of irrigation networks, summarized in Fig. 9. Adjustments in the weighting of the criteria can affect the ranking strategy for each alternative.

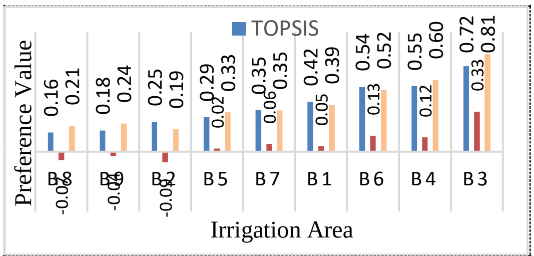


Fig. 9 Summarized of Ranking Priority for Rehabilitation of Irrigation Network

The results of a priority analysis show that B3 has the highest preference value for all methods, so it is the main priority for rehabilitation. B3 is on the top rank because it is affected by the most damage to irrigation structures conditions from other irrigation areas, about 89%. The second rank is B4 with a value for AHP-TOPSIS and AHP-WAPSAS, whereas B4 is in the third position if using AHP-MOORA. The second priority in the AHP-MOORA method is B6, whereas, on the third position in another process, B4 and B6 have a relatively small difference based on preference value. B6 had more severe damage to irrigation structures and a narrower irrigation area than B4.

On the other hand, B4 has less water availability and productivity than B6. This balanced advantage between B4 and B6 causes the two's preference values and priority positions to be close together. The last rank is B8 for AHP-TOPSIS and AHP-WASPAS, whereas the previous priority using AHP-MOORA is B2. Value of the criteria and the weight of the criteria that most influence the results of the analysis of the AHP-TOPSIS and AHP-WASPAS approach is the condition of irrigation structures and water availability. The AHP-TOPSIS method is a suitable method to combine in determining rehabilitation priorities because, according to [9], these two methods (AHP and TOPSIS) have the same pattern but differ in terms of value and process of parameter analysis or influencing factors. Among the three methods for rehabilitating irrigation networks, the preference is the AHP-TOPSIS, the AHP-WASPAS, and the AHP-MOORA.

## 5. CONCLUSION

This research contributes two things to the selection of rehabilitation for irrigation networks. Considering the goal of rehabilitation irrigation networks, the AHP integration method with various MDMCs is effective as a decision-making process. The integration of this approach can describe rehabilitation priorities based on four criteria that affect the performance of irrigation networks. The decision to rehabilitate the irrigation network by integrating the AHP method with TOPSIS, WASPAS, and MOORA gives a slightly different consideration.

The results of this research are: (1) the weighting of the four criteria as measured by the AHP method from expert judgment describes the damage to irrigation structures with the highest weight; (2) the decision matrix is processed by integration in the AHP-TOPSIS, and the AHP-MOORA method gives almost the same order of decisions (only three earlier positions). In contrast, integration with the AHP-TOPSIS and the AHP-WASPAS with lamda [0.9,1] method gives three different orders position of priority; (3) The variance influences the AHP-WASPAS method in each criterion.

The advantage of the hybrid of the AHP-TOPSIS and AHP-WASPAS approaches can be validated to measure ranking stability. However, the drawback of this method is that it always follows the weight criteria strength in the AHP, which is very dependent on expert judgment. The advantage of the AHP-MOORA method is that it can show partial priorities. The challenge to reduce the dependence on the expert judgment in future research is to use other methods independent from expert judgment by integrating TOPSIS, WASPAS, and MOORA to minimize imperfections. Another recommendation is to add more data for similar cases to combine weighting through various optimizations, such as genetic algorithms get more objective results.

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